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Title: *Evaluating Multiple Stressors in Loggerhead Sea Turtles: Developing: A Two-Sex Spatially Explicit Model.*

Investigators:
Jeanette Wyneken, Assistant Professor, (jwyneken@fau.edu), PI; Larry Crowder, Professor, , (lcrowder@duke.edu), CO-PI, Sheryan Epperly, Sea Turtle Team Leader NMFS (sheryan.epperly@nmfs.gov), Invest.
Institution: Florida Atlantic University, Duke University Marine Laboratory, National Marine Fisheries Service

Research Category: Wildlife
Project Period: November 2001-November 2004

Objective(s) of the Research Project: Our broad project goal is to integrate the effects of multiple stressors into population models to evaluate and advance contemporary management options for species conservation. We study loggerhead sea turtles as a model species in which we can integrate temporarily and spatially specific data collected (and mined from existing data sources) on males and females to develop a two-sex model.

Progress Summary/Accomplishments:

Overview

During the past year we continued data collection on spatial and temporal differences in loggerhead turtle sex ratios, assessed predation risks in waters adjacent to index nesting beach sites, and worked to update our conceptual model to better reflect what we know about spatial difference in loggerhead turtle life histories. We just completed spatially- and temporally-specific assessment of hatchling predation risks for the Florida Subpopulation. Completion of posthatchling loggerhead growth data in year two enabled us to update the durations (temporal exposures) of environmental stressors in our model. To date, we see are rethinking if male and female posthatchlings experience stressors differently.

Management alternatives frequently only address a particular life stage, sex, habitat or spatial location, so adding our results to assessments of the integrated population-level response and consideration of management trade-offs require a new generation of population models. Our conceptual approach to wildlife risk assessment for loggerhead turtles now is under consideration as a foundation for examining leatherback turtle and may subsequently be extended to other migratory, long-lived species.

Loggerhead Hatchling Survivorship and Predation Risks

Loggerhead hatchlings were followed as they migrated away from nesting beaches to determine the probable recruitment for each site. Hatchlings were successful if they were not lost to predators during their initial phase of the off-shore migration.

Hatchlings were followed from three beach sites, Boca Raton (N26°22′ W080°04′) and Hutchinson Island (N 27°20′ W 080°13′) on the east coast and Naples and Sanibel (N26°01′24

W081°46′) on the west coast of Florida. The predation rates were compared by early, middle and late season at each of the sites, and seasons were compared across sites. Based on previous studies, an overall predation rate of 5% was expected.

No data were collected from Hutchinson Island during the late season due to two hurricanes that made land fall directly over our field sites in September. Sanibel was not used during August or September due to the impact of Hurricane Charlie. There we moved to an adjacent and nearly identical beach at Naples to complete sampling. At all sites number of late season hatchlings produced was limited by the storms. We completed sex ratio and predation assessments where possible with nests that were moved into the lab before the 2nd hurricane made land fall. Data collected during the summer of 2003 and summer 2004 showed no significant difference in trends. The overall rate of predation did not differ significantly at any of the beaches from the expected rate of 5%. There was no significant difference in predation rates at the three sampling locations (Boca Raton, Hutchinson Island and Naples/Sanibel) across the early season or the mid season. Figure 1 illustrates the proportion of hatchlings predated during each of the subseasons at all beaches sampled in both 2003 and 2004. The percentage of predation observed for each sampling location during the sampling subseason can be seen in Figure 2. Predation levels were lower at the Florida west coast sites and when predation was relatively high, it was during the late subseason.

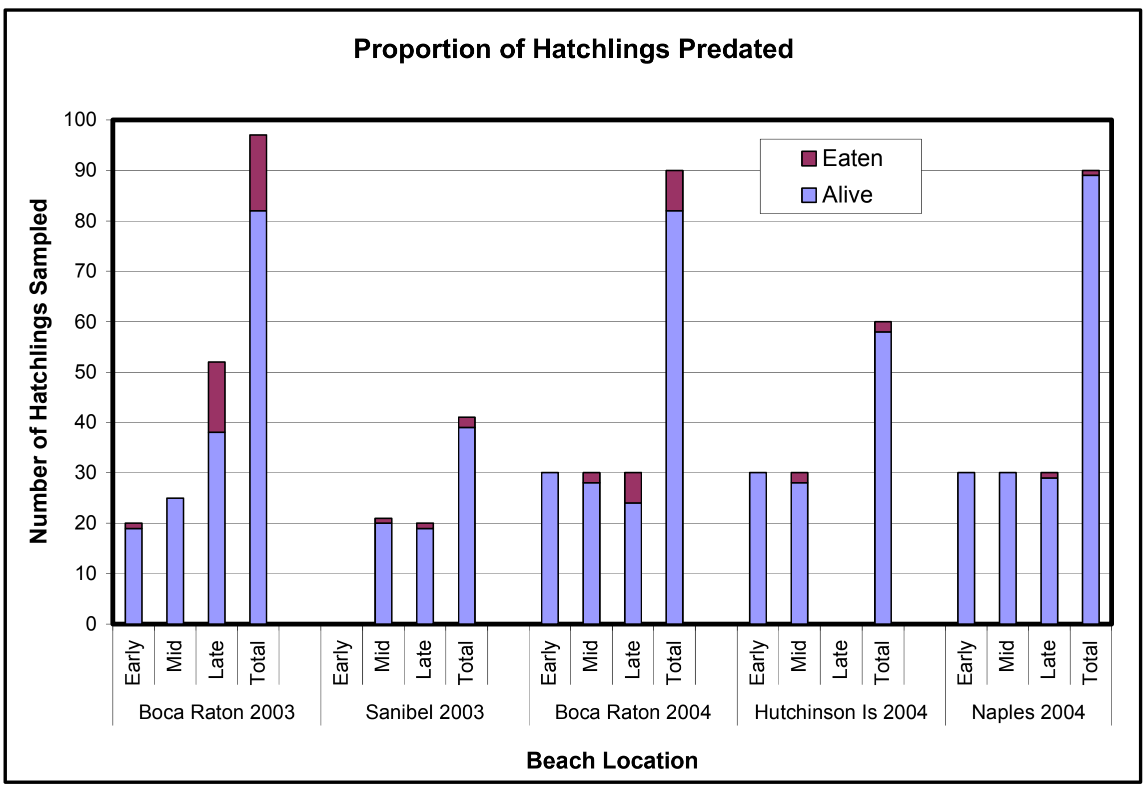


Figure 1: Proportion of hatchlings predated during early, middle and late sub seasons at all sampling locations.

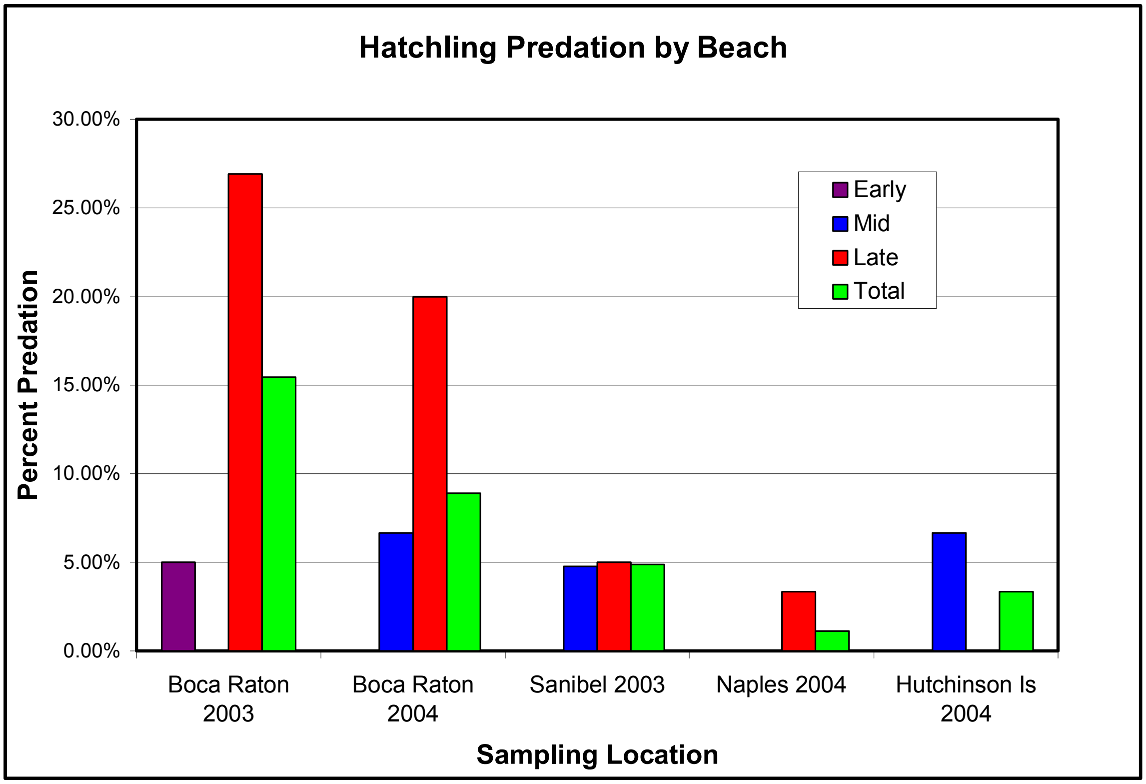


Figure 2: Percent hatchling predation by beach location during the early, middle and late sampling sub-seasons.

Scaling sex ratio data

Once we had established the sexes of individuals included in the study (Blair, in prep) we needed to scale up to estimate the sex ratio of hatchlings produced by beach surveyed and by seasonal time period. Our original study design required us to subsample 10 individuals for each of four nests on each beach in each time period. We marked nests to estimate sex ratios across the season. Because nest frequency is approximately normally distributed, we targeted nests around the mean nest date as well as the early and late standard deviation of the historical nesting distribution. So early, mid, and late season nesting represented about the first, second, and third one-third of nesting. This left us with 3 estimates of sex ratio at three points in the season. In order to estimate the sex ratio of hatchlings produced over the whole season, we calculated the cumulative frequency distribution of total nesting for each beach and overlaid the sex ratio estimates for the dates sampled. We then determined the midpoint date between sample dates and applied the sex ratio estimate to, for example, the early turtles through those eggs laid up to the midpoint date between the early and mid sample (cite the figure from Boca Raton for example) . In this way we can estimate the mean sex ratio produced on each observed beach in each year.

Once we know the sex ratio for each beach. We can use the three seasonal break points in sex ratios for each beach to estimate sex ratios produced in other years. By applying the empirical seasonal break points to the historical nest frequency distribution for each year over a period of years (often 15-20 years) we can estimate the mean and standard deviation of sex ratios produced on each beach and ultimately for each state. In order to estimate the mean and standard deviation of sex ratio for the two regional populations, we take the weighted mean of the sex ratio of hatchlings produced in area. For example the proportion of hatchlings produced in Georgia relative to other states representing Northern loggerheads will vary from year to year, but the weighted average of Georgia, South Carolina, and North Carolina for each year should represent well the overall northern population sex ratio.

Modeling report
Our original concept was to produce a spatially explicit population model that linked the northern and southern regional populations. The driving motivation was based on the idea that males produced in the northern population migrate to mate with females in the south, where too few males are produced. The status of the northern population is that it has 10X fewer nests per year than the southern population and is declining at 2-3 % per year (Loggerhead Recovery Team, in prep.). By contrast the southern population is much larger and approximately stable (Loggerhead Recovery Team, in prep.). But the previous literature suggested that the large southern population likely produced about 94% females (Mrosovsky and Provancha 1989, 1992), a nearly 16:1 sex ratio. We estimated that males would dominate the northern hatchlings (perhaps 75% male, NOAA 2001), so males produced in the north might well be critical not only to sustain populations in the north, but also to provide mates for the much larger southern loggerhead population.

Our original plan called for developing linked matrix models of both the northern and southern subpopulation. Each model includes key life stages occupying different habitats that might be differentially occupied by turtles from different regional subpopulations. We have thoroughly fleshed out a conceptual model (Fig. 3) that includes both sexes and allows for different spatial distributions of different subpopulations. Each habitat region could, in theory, represent different threats.

Our empirical sex ratio study shows two very interesting results. First, the southern population can produce a substantial proportion of males (57-86% female depending upon the beach in 2002), though 2003 produced a result more similar to the historical data (81-98% female). The year 2002 may have been anomalous, but it does show substantial capacity to produce males in the south in both years sampled. Second, hatchling output is not strongly male dominated in the north (averaging 75% female in 2002 and 47% female in 2003). The conclusion based on these data is that two assumptions critical to our motivation for linking the northern and southern subpopulation models may be faulty. The southern population appears to produce far more males that previously thought, so males may not be in extremely short supply. And the northern population is not a major source of males for the regional population. For example in 2002, the proportion of males produced in the south (32%) exceeded that produced in the north (25%) and the south produced about 10x more hatchings.

All this has led us to the idea that developing independent models for the south and for the north has a higher priority than developing a linked model at this time. We retain the two-sex, spatially explicit approach, but our priorities have shifted toward updating the northern model and deriving parameters to flesh out a southern model. Thus our new strategy involves checking updates for the northern population model (improved growth rate and adult survival estimates.

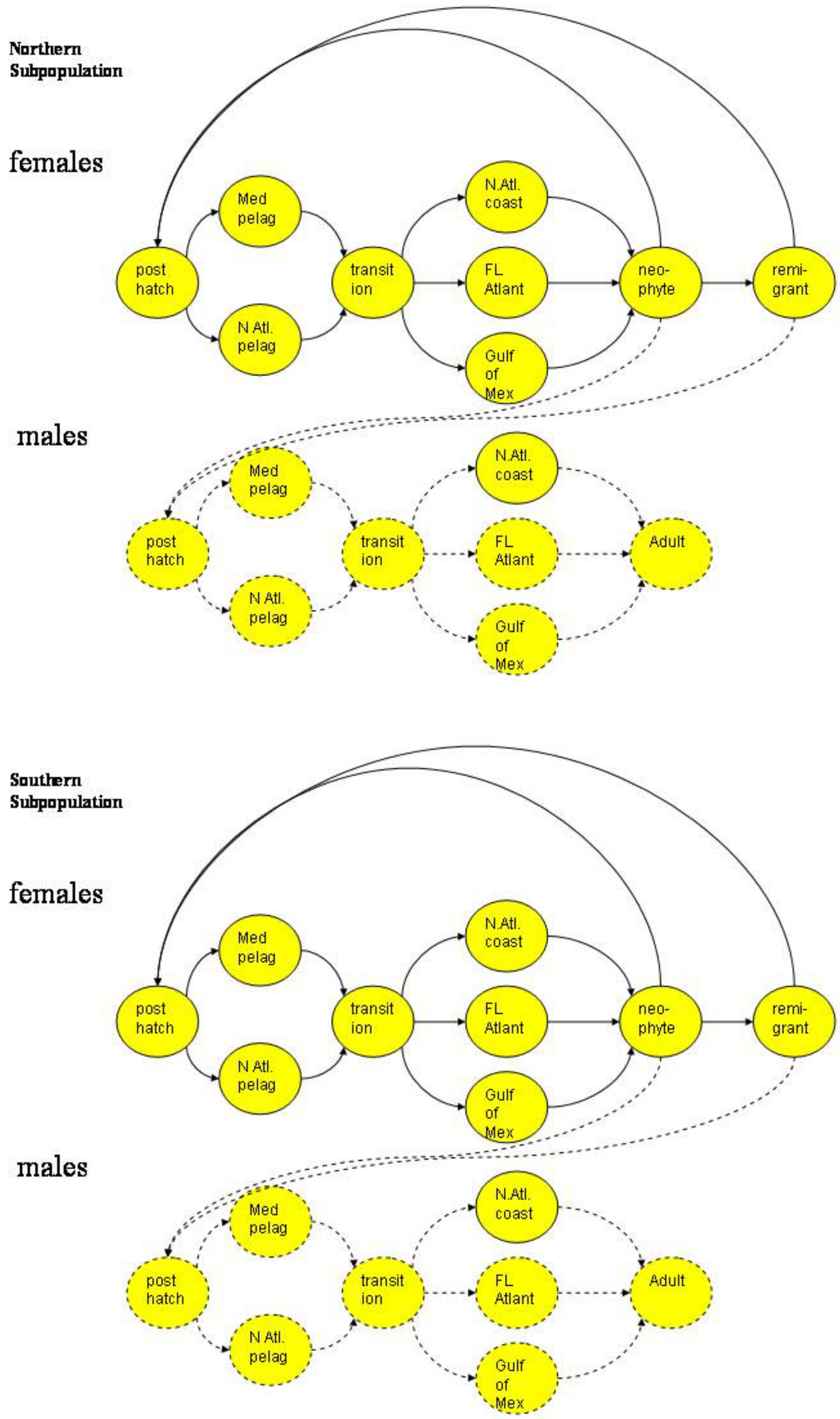


Figure 3. These two-sex spatially explicit population models remain separate for the two subpopulations. The two subpopulations are treated identically at present.

from mark-recapture data) as well as establishing new vital rate estimates for the southern population (growth and survival rates from in-water sampling programs – Indian River Lagoon and Hutchinson Island as well as adult survival rates from beach mark recapture programs

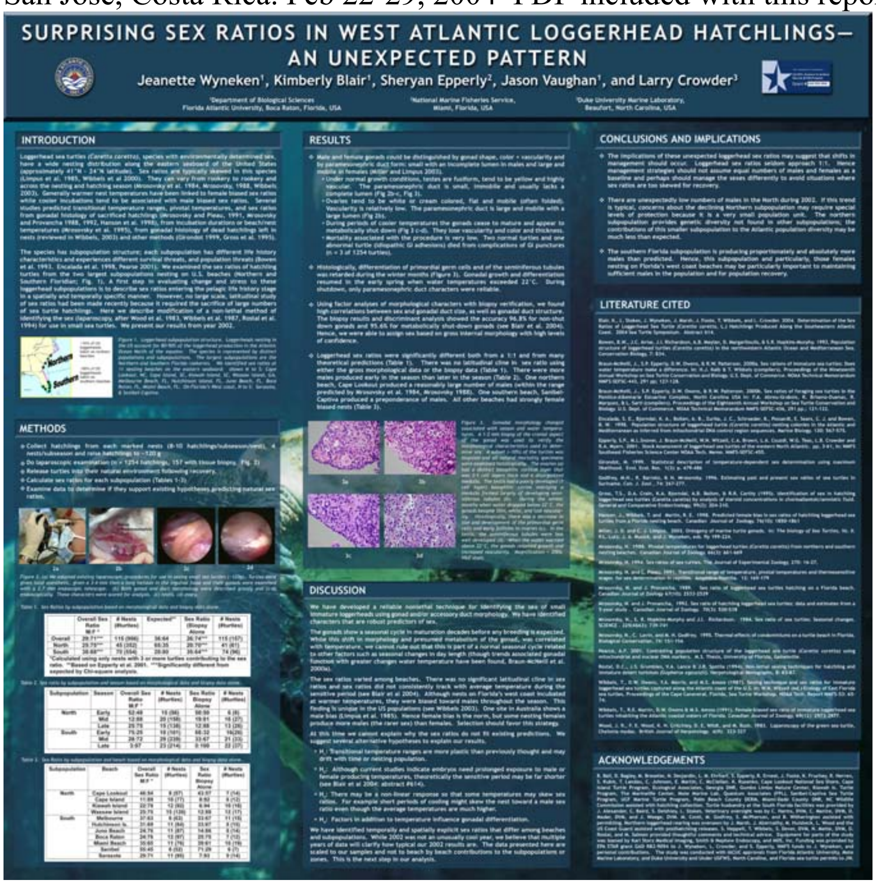
We don't plan to abandon the idea of linking the regional matrix models, but the empirical data point to the value fleshing out and updating the regional models before we worry about the linkage issues. The genetic data suggest the regional subpopulations are linked, but infrequent matings could provide genetic homogeneity at the nuclear DNA level without having significant population dynamics consequences.

Publications/Presentations/Media Coverage:

Oral and Poster Presentations at Professional Meetings

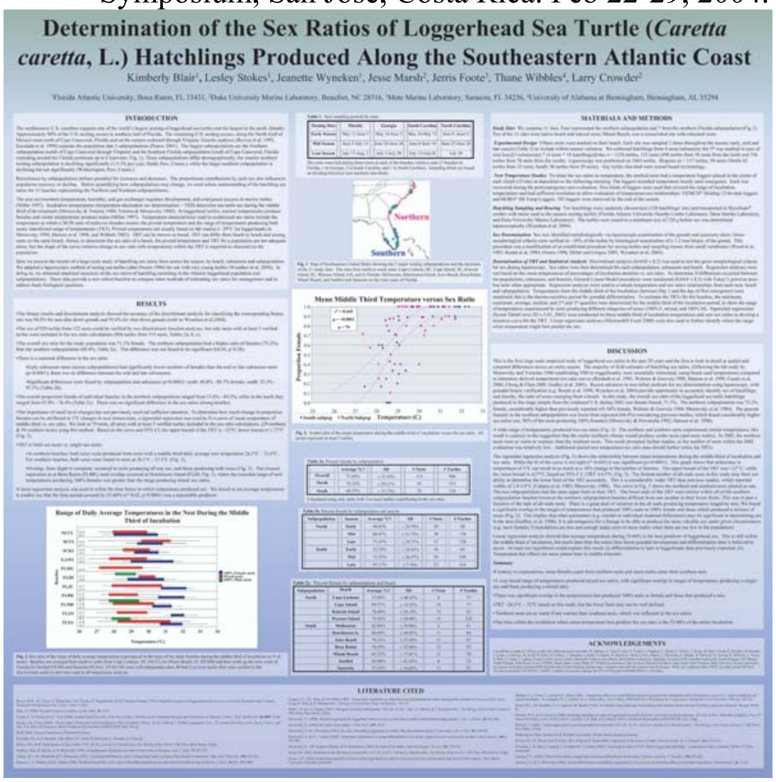
Wyneken, J.; Vaughan, J., Blair, K.; Epperly, S. Natural sex ratios and posthatchling gonadal development in posthatchling loggerhead sea turtles (*Caretta caretta*). Society for Integrative and Comparative Biology. 6 January 2004. New Orleans, LA.

Wyneken, J, K. Blair, S. Epperly, J. Vaughan, and L. Crowder. Surprising Sex Ratios In West Atlantic Loggerhead Hatchlings – an unexpected pattern. International Sea Turtle Symposium, San Jose, Costa Rica. Feb 22-29, 2004 PDF included with this report.

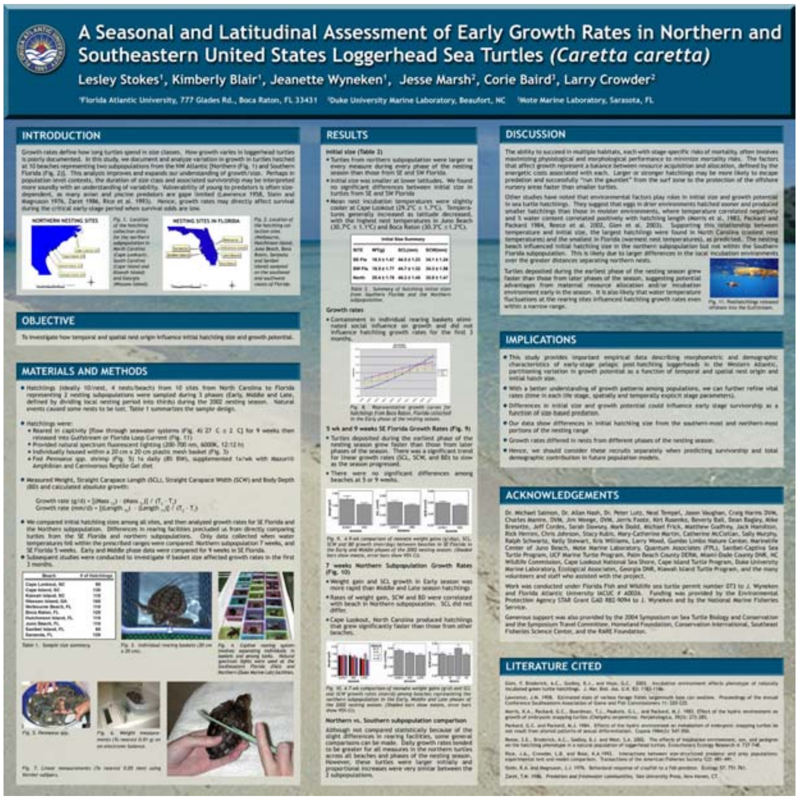


- Juan José Alava, Jennifer M. Keller, John R. Kucklick, Larry Crowder, Jeanette Wyneken, and Geoffrey Scott. Analysis of polychlorinated biphenyls (pcbs) and organochlorine pesticides in loggerhead sea turtle eggs from Florida, U.S. International Sea Turtle Symposium, San Jose, Costa Rica. Feb 22-29, 2004.

- Blair, K. Stokes, L., Wyneken, J, Marsh, J, Foote, J., Wibbels, T., and Crowder, L. Determination of the Sex Ratios of Loggerhead Sea Turtle (*Caretta caretta* L.) Hatchlings Produced Along the Southeastern Atlantic Coast. International Sea Turtle Symposium, San Jose, Costa Rica. Feb 22-29, 2004. pdf included with this report.



Stokes, L., Blair, K., Wyneken, J. Marsh, J., Baird, C. and Crowder, L. A seasonal and latitudinal Assessment of Early Growth Rates in Northern and Southeastern United Sates Loggerhead Sea Turtles (*Caretta caretta*). International Sea Turtle Symposium, San Jose, Costa Rica. Feb 22-29, 2004. pdf included with this report.



Oral Presentations

- Florida Atlantic University, Board of Trustees Tour and Reception –FAU Gumbo Limbo Marine Laboratory tour of research

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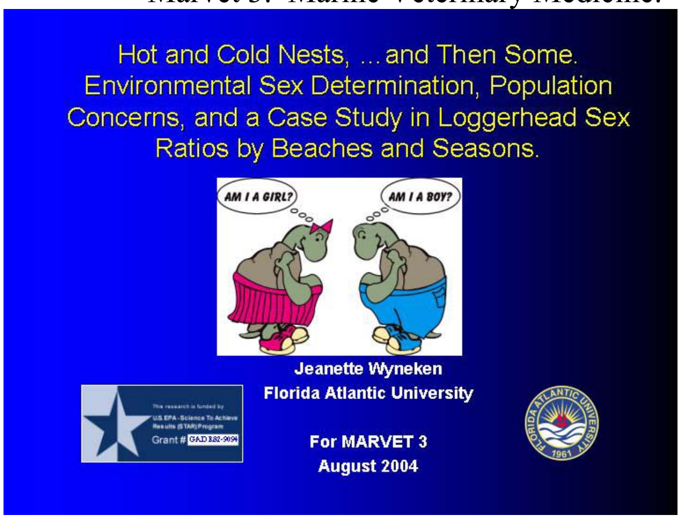
- FAU 40th Anniversary President's State of the University Presentation http://www.fau.edu/webcast/state/statewebcast.html

- Save-A-Turtle Lecture Series, Marathon Florida, April 2004.

- Marvet 3. Marine Veterinary Medicine. Georgetown, Granada. August 2004.



Media Coverage

In all cased where media coverage occurred, the media were told that the study was funded by the EPA Star program and we have requested that they include such information. We note that it remains difficult and continually frustrating to get editors to include such funding information.

Grimm, D. 2004. Science weathers the Storms. Science 306:37-39.

Future Activities: Our first goal is to retrieve outstanding data from those sites that were unable to meet our deadlines because of storm damage to their facilities. With regard to our models, as we described above, our priorities are to updating the northern subpopulation model and work to more fully develop and identify parameters for our southern subpopulation model. New data describing and clarifying vital rate estimates for the southern population (growth and survival rates from in-water sampling programs – Indian River Lagoon and Hutchinson Island, as well as adult survival rates from beach mark recapture programs are what we are working with now. The remaining activities include completing data transfer from beach managers who promised historical data quantifying daily hatchling production, as well as working with mark and recapture data to include in our model. We will also complete analyses of predation results and the second year of sex ratio data collection for the remaining Florida sites to modify estimates of male and female hatchling production (the 1st year in the life history tables). Additionally we will up date the conceptual model and apply our new data as appropriate.

Supplemental Keywords: animal, reptiles, population biology, habitat degradation, indicators, temperature dependent sex determination, matrix population models, mark-recapture, aquatic, marine sciences, midAtlantic, zoology, toxics, sex, ecological effects

Relevant Web Sites:
http://www.fau.edu/webcast/state/statewebcast.html